WORKING PAPER NO. 57

Regulatory Reform of Japan's Electric Power Industry: Economies of Scale-and-Scope and Yardstick Competition

Takanori Ida
Graduate School of Economics, Kyoto University, Japan
Tetsuya Kuwahara
Kansai Electric Power Co., Japan

July, 2002

Graduate School of Economics
Faculty of Economics
Kyoto University
Kyoto, 606-8501 JAPAN

Regulatory Reform of Japan' s Electric Power Industry: Economies of Scale-and-Scope and Yardstick Competition

Takanori Ida
Graduate School of Economics, Kyoto University, Japan
Tetsuya Kuwahara
Kansai Electric Power Co., Japan

July, 2002

Regulatory Reform of Japan's Electric Power Industry: Economies of Scale-and-Scope and Yardstick Competition

Takanori Ida

Kyoto University, Faculty of Economics, Japan

and

Tetsuya Kuwahara

Kyoto University, Faculty of Economics, Japan

Address:

Takanori Ida

E-mail: ida@econ.kyoto-u.ac.jp

12-7-104 Hattyo-nawate, Takatsuki, Osaka 569-0096, Japan

Running head:

regulatoryreform

Regulatory Reform of Japan's Electric Power Industry: Economies of Scale-and-Scope and Yardstick Competition

Abstract:

This paper utilizes the fixed-effect model of the panel-data analysis and estimates the translog cost function of the Japanese electric power industry from 1978 to 1998. First, we investigate whether the Japanese electric power industry has been naturally monopolistic or not. We find that all electric power companies still benefit from both scale and scope economies and therefore this industry remains a natural monopoly where we cannot expect a competition will automatically function. Second, in order to apply the idea of yardstick-type competition even to the naturally monopolistic industry where costs are quite different between companies, we introduce two kinds of cost-comparison coefficients for the individually specific effect and the scale-and-scope economies respectively.

Keywords:

electric power industry, regulatory reform, yardstick competition, economies of scale, economies of scope

I. Introduction

A wave of liberalization is sweeping in the Japanese electric power industry that was previously a monopolistic industry. The entry regulation of power generation was abolished and a bidding system for the wholesale acquisition of electric power was introduced in 1995. Furthermore, the partial liberalization of the retail section started for the large-volume users from 2000. At this point, it will be necessary to examine the meaning of "monopoly" before arguing whether liberalization brings about an improvement in industrial efficiency. There are two types of monopoly: legal monopoly and natural monopoly. Even if legal monopoly is abolished, in the case where the industrial structure still remains naturally monopolistic, the economic significance of liberalization will be limited. In this sense, such a mechanism design as yardstick competition, which was introduced to some extent to the Japanese electric industry in 1995, is required so that electric power companies endeavor to manage more efficiency.

This paper will investigate the cost structure of Japan's nine incumbent power companies (except the Okinawa Electric Power) over the past 20 years by using the translog cost function which is the most widely used flexible function in the cost estimation of public utilities. At the same time, we will adopt the fixed-effect model of panel data analysis, utilize the information about the individually specific effects of electric power companies, and measure the cost-comparison coefficients[1]. The contribution this paper seeks to make is not only to verify whether the natural monopoly of the Japanese electric power industry still remains but also to measure the cost-comparison coefficients so that a more refined incentive regulation for improving efficiency will be introduced even to an industry where we can not expect effective competition because of its strong natural monopoly[2].

There are two main conclusions in this paper. Firstly, when the verification of the economies of scale-and-scope is carried out in the Japanese electric power industry, it is clearly observed that the economies of scale-and-scope are widespread. Therefore, we can conclude that the Japanese electric power industry is still an industry of naturally monopolistic character. (For all that, it does not necessarily mean that the classical public utilities regulation is valid.) Secondly, we measure the cost-comparison coefficients from two different viewpoints: the economies of scale-and-scope and the individually specific effect. A cost-comparison coefficient is multiplied by the individual average cost of a power company, and the adjusted average costs obtained in this way can be compared, and accordingly we can introduce a refined yardstick competition into the industry where the assumption of equality of average costs among companies is seldom satisfied. In addition, we can expect a contribution to policy-making in universal service support that advocates fair supply of service in the whole country since the difference in the average cost between areas is explicitly calculated.

The paper consists of the following nine sections. Section II surveys the history of the Japanese electric power industry and Section III introduces definitions of variables and a method of estimating the cost function. Section IV provides the definition of economies of scale-and-scope, while Section V carries the result of the test of economies of scale-and-scope. The paper further develops its theme by presenting in Section VI definitions of cost-comparison coefficients, with Section VII carrying the result of the measurement of cost-comparison coefficients. Section VIII examines the implications for policy discussion. Section IX draws a final conclusion.

II. A Historical Overview of the Japanese Electric Power Industry

It will be informative, before moving to the main subject, to provide a brief overview of the liberalization in the Japanese electric power industry. In May 1951, a system was set up that divided the nation into nine areas with a single company to generate, transmit and deliver power in each area[3]. Before that, power generation and transmission had been consolidated in the Japan Electric Generation and Transmission Company during the war, with nine local distribution companies handing power distribution, all of which were under government control. In1964, Japan promulgated the Electric Utility Industry Law with the objective of deregulating the industry, improving efficiency in the private sector, and simplifying and rationalizing the government's policy on electric power. Figure 1 geographically displays Japan's nine incumbent electric power companies.

<Figure 1>

Untouched for 31 years, the Electric Utility Industry Law was extensively amended in April

1995 with particular focus on lifting restrictions on who could participate in the wholesale power generation market and instituting an across-the-board review of safety regulations. Those amendments were enacted in December that same year. Some of the major changes included the introduction of a supply bidding system from power wholesalers, the activation of wholesale transferable supply, and the creation of a new type of power provider. In terms of cost, a yardstick assessment and control system were introduced. In 1996, six power companies accepted supply bids from power wholesalers. The competitive rate was 4.1 times. Seven companies accepted bids in 1997, while only one did so in 1998. In May 1997, the Cabinet adopted an Action Plan on Economic Structural Reform and Creation that aimed for "internationally competitive electricity rates by the year 2001". In July that year, a Basic Policy Committee was set up in the Electric Utility Industry Council to make a complete review of Japan's power supply system. In January 1999, the Basic Policy Committee released a report that called for partial liberalization in the power retail market. It was directed at high demand power users that require 2000 kW or more of 20,000 V or higher voltage supply. In February that year, the cabinet proposed revisions to the Electric Utility Industry Law based on this report. The revisions were passed into law in May that same year. The revisions went as far as designing rules on network use, enactment of final guarantee covenant and determining consignment rates. In March 2000, a revised Electric Utility Industry Law was enacted. Tokyo, Kansai and Hokuriku Electric Power companies submitted a new rate menu for unregulated areas in anticipation of broader liberalization in the future. In June, Mitsubishi Corporation subsidiary Diamond Power applied for approval as a power producer and supplier (PPS) in the power retail market. In August, the Ministry of International Trade and Industry accepted bids from power providers to supply their needs and Diamond Power won in the first case ever of a winning bid being tendered by a new entrant to the retail market.

A study of partial liberalization in the power retail market and a review of existing systems with the objective of expanding liberalization are planned for 2003. To sum up, since Japan's regulatory reform tends to be very slow and built on compromise, a radical remedy, including functional or structural unbundling or the promotion of convergence between the electric power industry and gas industry, will be required.

III. The Definitions of Variables and the Estimation of Translog Cost Function

This section provides definitions and sets out a method to be used. We assume in this paper that there are two kinds of outputs in the electric power industry, the power generation (Y_1) and the power transmission-and-distribution (Y_2), and there are three kinds of production inputs, labor force (L), fuel (F), and capital (K)[4]. The definitions of variables are given as follows. (Note: each variable is normalized by its mean.)

Outputs:

Generation; $Y_1 \equiv$ the generated output – the station-use electricity,

Transmission-and-distribution; $Y_2 \equiv$ ([Σ(the middle value of the voltage spectrum × the route length of transmission lines)] × the number of contracts/customers)$^{1/2}$.

Inputs and their expenses[5]:

Labor-input cost; $P_L \equiv$ (the total personnel expenses – the expenses of consignment meter-reading and consignment payment collection) / the number of regular employees at the end of the fiscal year,

Fuel-input cost; $P_F \equiv$ (the total fuel expenses for steam, internal combustion engine and nuclear power generation) / the heat consumption of conversion into heavy oil,

Capital stock; $K_t \equiv (1-\delta_t)(K_{t-1} - LAND_{t-1}) + I_t + LAND_t$,

Note: $\delta_t \equiv$ the depreciation expenses at t / the equipment expenses at the end of t-1, $LAND_t \equiv$ the land values at t = $LAND_{t-1} + \Delta LAND_t$, $I_t \equiv K_t - K_{t-1} - \Delta LAND_t$ + depreciation expenses at t.

Capital cost; $P_K \equiv [WPI(r_t+\delta)(1-u_t z_t)] / (1-u_t)$,

Note: WPI $\equiv$ the price indexes of investment goods, $r_t \equiv$ the interest payments at t / (the corporate bond + the long-term loan at the beginning of t-1), $u_t \equiv$ the corporation-tax rate, $z_t \equiv$ the ratio of the present value of the deduction of depreciation expenses to that of capital goods.

The other definition:

Capacity utilization rate of power plants; CU $\equiv$ the generated output / the installed generating capacity.

The terms, a, b, c, d, e, and f, are coefficients to be estimated. The long-term translog cost function, all of whose inputs we assume here are variable, can be defined as follows, taking the symmetry of coefficients into consideration[6]:

$$\ln C(P_L,P_F,P_K,Y_1,Y_2,t,CU) =$$

$$a_i+b_L\ln P_L+b_F\ln P_F+b_K\ln P_K+(1/2)b_{LL}(\ln P_L)^2+(1/2)b_{FF}(\ln P_F)^2+(1/2)b_{KK}(\ln P_K)^2$$
$$+b_{LF}\ln P_L\ln P_F+b_{LK}\ln P_L\ln P_K+b_{FK}\ln P_F\ln P_K+c_1\ln Y_1+c_2\ln Y_2+(1/2)c_{11}(\ln Y_1)^2$$
$$+(1/2)c_{22}(\ln Y_2)^2+c_{12}\ln Y_1\ln Y_2+d_{L1}\ln P_L\ln Y_1+d_{L2}\ln P_L\ln Y_2+d_{F1}\ln P_F\ln Y_1$$
$$+d_{F2}\ln P_F\ln Y_2+d_{K1}\ln P_K\ln Y_1+d_{K2}\ln P_K\ln Y_2+\Sigma_{t=1\ldots 21}e_{Lt}\ln P_L D_{Lt}+\Sigma_{t=1\ldots 21}e_{Ft}\ln P_F D_{Ft}$$
$$+\Sigma_{t=1\ldots 21}e_{Kt}\ln P_K D_{Kt}+f_1t+f_2t^2+f_{cu}\ln CU. \qquad (1)$$

It is noted that D_{it} for i=L, F, K represents the dummy variable of inputs costs while a_i for i=1...9, represents the constant term of each power company. Since the fixed effect model is used here with the panel data of nine power companies from 1978 to 1998, the estimated coefficient a_i represents what is called "individually specific effect" of each power company. In addition, the following constraints of linear homogeneity is imposed in advance on the cost function given above:

$$b_L+b_F+b_K=1,\ b_{LL}+b_{LF}+b_{LK}=0,\ b_{FF}+b_{FL}+b_{FK}=0,\ b_{KK}+b_{LK}+b_{FK}=0,\ d_{L1}+d_{F1}+d_{K1}=0,$$
$$d_{L2}+d_{F2}+d_{K2}=0,\ e_{Lt}+e_{Ft}+e_{Kt}=0. \qquad (2)$$

From the Shepherd lemma, the share equations of inputs are obtained as follows :

$$S_L=b_L+b_{LL}\ln P_L+b_{LF}\ln P_F+b_{LK}\ln P_K+d_{L1}\ln Y_1+d_{L2}\ln Y_2+\Sigma_{t=1\ldots 21}e_{Lt}D_{Lt},$$
$$S_F=b_F+b_{FF}\ln P_F+b_{LF}\ln P_L+b_{FK}\ln P_K+d_{F1}\ln Y_1+d_{F2}\ln Y_2+\Sigma_{t=1\ldots 21}e_{Ft}D_{Ft},$$
$$S_K=b_K+b_{KK}\ln P_K+b_{LK}\ln P_F+b_{FK}\ln P_F+d_{K1}\ln Y_1+d_{K2}\ln Y_2+\Sigma_{t=1\ldots 21}e_{Kt}D_{Kt}. \qquad (3)$$

(Note: since the sum of three share equations must be one, one of them can be dropped.)

We can now estimate the simultaneous equations of the long-term translog cost function and the share equations except the capital one by Zellner's seemingly unrelated regressions model (SUR). Table 1 indicates the main result of the estimation[7]. The result of the estimation appears to be fairly good[8].

<Table 1>

IV. The Definition of the Economies of Scale-and-scope

Due to the characteristic known as 'bottleneck' or 'essential facility' that arises from the huge plants and equipments of power generation, transmission, and distribution, the electric power industry has conventionally been considered to be naturally monopolistic. Natural monopoly is defined by the subadditivities of cost. As is well known, the necessary and sufficient condition that the subadditivities of cost equal to the economies of scale-and-scope does not exist in a case of multi-goods[9]. However, it is the sufficient condition of being a natural monopoly that the economies of scale exist in each good and the economies of scope hold. Although there are various kinds of index for the economies of scale-and-scope, the following are used in this paper[10].

The index of overall economies of scale

$$\equiv 1-[Y_1(\partial C(Y_1,Y_2)/\partial Y_1)+Y_2(\partial C(Y_1,Y_2)/\partial Y_2)]/C(Y_1,Y_2) \qquad (4)$$

It is judged here that if this figure is positive (negative), the overall economies of scale (the diseconomies of scale) exist. Besides, the degree of scale economies becomes progressively smaller as the figure is closer to 0, while the former becomes larger as the latter is closer to 1.

The economies of scale of each good i $\equiv 1 - \partial \ln C(Y_1, Y_2) / \partial \ln Y_i$ (5)

If this figure is positive (negative), the economies of scale of each good i (the diseconomies of scale) exist. Again, the degree of scale economies becomes progressively smaller as the figure is closer to 0, whereas the former becomes larger as the latter is closer to 1.

The economies of scope $\equiv \partial^2 C(Y_1, Y_2)/(\partial Y_1 \partial Y_2)$ (6)

If this figure is negative (positive), the economies of scope (the diseconomies of scope) exist between two goods[11].

V. The Result of the Verification of the Economies of Scale-and-Scope

Table 2 indicates the result of the verification of the economies of scale-and-scope at the point where the figures are mean values. The following can be observed here: since the economies of scale, overall or product-specific, are all positive, this proves that the economies of scale exist on average; and since the economies of scope are negative, this shows that the economies of scope exist on average. All these results are statistically significant at the 5% level.

<Table 2>

Let us discuss more fully the observations above. We will divide the whole period into four sub-periods: 1978-83, 1984-88, 1989-93, and 1994-98. Table 3 indicates the result of the verification of the economies of scale-and-scope of each electric power company during each period; Figure 2 displays the index of each company on average in the period 1978-98. To begin with, several points can be made concerning the economies of scale as follows:

(1) Based on the index of scale economies, on the whole, we can classify electric power companies into three groups: the first is one that has historically benefited considerably from scale economies such as Tokyo, Chubu, and Kansai operating in the three largest metropolitan areas, namely Tokyo, Nagoya, and Osaka (as for the average (1978-98) overall-scale-economies, these figures are 0.3242, 0.4349, and 0.3928, respectively); the next is made up of one whose scale economies are intermediate such as Hokkaido, Chugoku, and Kyushu operating in the urban areas, like Sapporo, Hiroshima, and Fukuoka (these figures are 0.5565, 0.5141, and 0.5253, respectively); and the last is one that has failed to make the most of scale economies such as Tohoku, Hokuriku, and Shikoku operating in rural areas (these figures are 0.6341, 0.6477, and 0.6108, respectively)[12]. Although Tokyo Electric Power is by far and away the largest company in Japan, it can be even now receiving benefits from the economies of scale.

(2) It is reasonable to conclude that the economies of scale appear to be fairly steady in the long run (as for the national average overall-scale-economies, these figures are 0.5064 (1978-83), 0.5107 (1984-88), 0.5215 (1989-93), and 0.5238 (1994-98)); however, that of power generation rose once in the 1980s but fell afterwards (as for the national average product-specific scale economies of Y_1, these figures are 0.5940 (1978-83), 0.6204 (1984-88), 0.6043 (1989-93), and 0.5931 (1994-98)), while that of transmission-and-distribution fell once in the 1980s but rose afterwards (as for the national average product-specific scale economies of Y_2, these figures are 0.8924 (1978-83), 0.8691 (1984-88), 0.8884

(1989-93), and 0.8970 (1994-98)).

(3) The scale economies of transmission-and-distribution are clearly larger than that of power generation (as for the national average (1978-98) product-specific-scale-economies, these figures are 0.6029 for Y_1 and 0.8867 for Y_2). This indicates that the characteristics of bottleneck or essential facility are stronger in the transmission-and-distribution section than in the power-generation section.

<Table 3>

<Figure 2>

Next, a few points will be made concerning the economies of scope as follows:

(1) Based on the index of scope economies, on the whole, we can classify electric power companies into three groups: the first that has benefited from scope economies such as Tokyo and Kansai (as for the average (1978-98) scope-economies, these figures are –0.0501 and -0.0891, respectively); the next is made up of one whose scope economies are intermediate such as Hokkaido, Tohoku, Chubu, Chugoku, Kyusyu (as for the average (1978-98) scope-economies, these figures are –0.3265, -0.1632, -0.1421, -0.2732, and –0.1927, respectively); the last that has failed to make the most of scope economies such as Hokuriku, Shikoku (as for the average (1978-98) scope-economies, these figures are -0.8920 and -0.6050, respectively).

(2) Even the largest electric power company, Tokyo Electric Power, is still enjoying benefits from the economies of scope. It is observed, however, that the economies of scope tend

to fall in the long run (as for the national average scope-economies, these figures are –0.3828 (1978-83), -0.3379 (1984-88), -0.2722 (1989-93), and –0.2172 (1994-98)).

It should be concluded from what has been said above that since both the economies of scale in each good and the economies of scope exist, the Japanese electric power industry is still naturally monopolistic even today. Even if an industry is naturally monopolistic, it may not put up barriers to entry and exit in a contestable market. However, we cannot suppose that the Japanese electric power industry is highly contestable because contestability requires strict conditions, such as no existence of sunk cost and the symmetry of demand and cost environments between an incumbent and an entrant. Therefore, it cannot be expected that the efficiency of resource allocation will be realized automatically only by abolishing the legal monopoly of Japan's electric power company.

VI. The Definition of Cost-comparison Coefficients

It is in this section that a yardstick-type incentive regulation with cost-comparison coefficients will be discussed. This policy aims to introduce more competition even in the naturally monopolistic and uncontestable industry where we cannot expect the intense competition is particularly effective. It is sometimes pointed out that the yardstick-type comparison of business performance provides strong incentives to executive officers for improving management efficiency. However, as is well known, the yardstick competition would not be effective without the symmetry of costs among firms. Therefore, it is necessary in the assessment of yardstick-type that respective cost is multiplied by the cost-comparison coefficient and in this way the cost heterogeneity between companies is leveled so that a comparison can be made. We will show how to derive the cost-comparison coefficients with the fixed effect model of panel-data analysis in the following section.

The cost function estimated in Section 3 is broken down into the individually specific effect and the other common portion, and we call the latter a "standard cost function". If the cost function of the company j is defined as C_j, the individually specific effect as K_j, and the standard cost function as c_0, then we obtain the next formula: $C_j(Y_1, Y_2) = K_j + c_0(Y_1, Y_2)$. Let us simply assume that j=A,B and $K_A=0$. (Note: the company A is set the Kyushu Electric Power in this paper.) Besides, since the case of two goods is considered in this paper, the Euclid distance, $[(Y_1)^2+(Y_2)^2]^{1/2}$, of the numerical value of outputs, $Y=(Y_1,Y_2)$, are defined as the total output, $\|Y\|$, and the total cost of the company j divided by its total output, $C_j(Y_1,Y_2) / \|Y_j\|$, is considered as the average cost of the company j, A C_j[13]. It is from what has been discussed that the cost-comparison coefficients of company B in comparison with that of company A can be defined as follows. See also Figure 3.

<Figure 3>

The cost-comparison coefficients of company B of the individually specific effect[14]:

$$\alpha = \frac{AC_A(Y_B)}{AC_B(Y_B)} = \frac{c_0(Y_B)/\| Y_B \|}{(K_B + c_0(Y_B))/\| Y_B \|}. \tag{7}$$

The cost-comparison coefficients of company B of the economies of scale-and-scope[15]:

$$\beta = \frac{AC_A(Y_A)}{AC_A(Y_B)} = \frac{c_0(Y_A)/\|Y_A\|}{c_0(Y_B)/\|Y_B\|}. \tag{8}$$

The overall cost-comparison coefficients of company[16]:

$$\gamma = \frac{AC_A(Y_A)}{AC_B(Y_B)} = \frac{c_0(Y_A)/\|Y_A\|}{(K_B + c_0(Y_B))/\|Y_B\|)} = \frac{AC_A(Y_B)}{AC_B(Y_B)}\frac{AC_A(Y_A)}{AC_A(Y_B)} = \alpha\beta. \tag{9}$$

VII. The Measurement Result of the Cost-Comparison Coefficients

Having defined the cost-comparison coefficients, we will move on to the examination of the result. We will again divide the whole period into four sub-periods: 1978-83, 1984-88, 1989-93, and 1994-98. Table 4 represents the result of the cost-comparison coefficients of the Japanese electric power companies. Moreover, the cost-comparison coefficients of each electric power company on average in the period 1978-98 are plotted in Figure 4. It is noticeable that the higher the cost-comparison coefficient is the cheaper the electricity production cost is, since the average costs of electric power companies are multiplied by the cost-comparison coefficients to carry out the yardstick-type assessment.

<Table 4>

<Figure 4>

We can observe the following points:

(1) The individual effect coefficients, α, and the scale-and-scope economy coefficients, β, tend to move in opposite directions, and the overall coefficients, γ, remain relatively

steady around 1. It may be that electric power companies are divided into three groups according to α and β. In the large-company group such as Tokyo, Chubu, and Kansai α is lower than 1, representing the disadvantageous individual effect (these figures are 0.5835, 0.8582, and 0.7466, on average in the period 1978-98), while β is higher than 1, representing the advantageous scale-and-scope economies (these figures are 1.7292, 1.2395, and 1.4598, on average in the period 1978-98). In the group of medium-sized companies such as Tohoku, Chugoku, and Kyusyu both α and β are almost 1 (these figures are 1.0940/1.0319, 1.1697/0.8866, and 1.000/1.000, on average in the period 1978-98). In the group of small companies such as Hokkaido, Hokuriku, and Shikoku α is higher than 1, representing the advantageous individual effect (these figures are 1.6517, 1.9293, and 1.6937, on average in the period 1978-98), while β is lower than 1, representing the disadvantageous scale-and-scope economies (these figures are 0.8182, 0.5258, and 0.6548, on average in the period 1978-98).

(2) Comparing the adjusted average costs between companies that are multiplied by the overall cost-comparison coefficients, γ, we can carry out the yardstick-type assessment of the Japanese electric power industries. In the case of $\gamma>1$, the average cost before adjustment is thought to be lower; on the other hand, in the case of $\gamma<1$, the average cost before adjustment is thought to be higher. When the cost-comparison coefficients in the period 1994-98 are taken as examples based on Kyushu Electric Power, the average costs of Hokkaido will be compared by the increase of 40.2%, Tohoku by the increase of 14.4%, Tokyo by the decrease of 0.3%, Chubu by the increase of 5.1%, Hokuriku by the increase of 0.2%, Kansai by the increase of 8.8%, Chugoku by the increase of 1.7%, Shikoku by

the increase of 10.7%[17]. However, as the numerical values of overall coefficients, γ, seem to fluctuate year by year, a frequent revision of the assessment will be desirable.

VIII. Some Policy Discussions

In this section, we will discuss some implications for the policy, based on the empirical foundations obtained so far. First, this paper made it clear in section V that the Japanese electric power industry has always been naturally monopolistic. This tendency is stronger than in the transmission-and-distribution section than in the power generation section. Therefore, if we leave this industry without any scheme, we cannot expect that its efficiency will automatically improve so much. Even so, we are opposed to the traditional idea that we should publicly regulate the electric power industry as strictly as before. On the contrary, we support the modern idea that a regulatory reform should be carried out in order to give incentives for efficient managements even to a naturally monopolistic industry. There are a gradual way and a radical way of moving towards regulatory reform. The gradual method is to introduce an indirect or partial competition into the electric power industry and then to enlarge the scope of competition little by little, given that the current industrial structure does not change in the short term. An example of indirect competition is the comparative assessment of the de facto regional monopolies in order to give them incentives for cost curtailment. As another example, the partial introduction of competition is to promote new entrants into an area, such as power generation, whose natural monopoly is relatively weak.

Such competitive policies have actually been adopted in Japan. To take one example, a yardstick regulation was introduced into the charge examination of electric power and gas industries by the Agency of Natural Resources and Energy, under the umbrella of the Ministry of International Trade and Industry, in January 1996. Two kinds of assessments were made to compensate fairly the cost and demand conditions for every company as follows; (1) the individual assessment: the verification of the validity of cost of each company, and (2) the comparative assessment: the comparison of the level of cost and the rate of change of cost of each company. The conditions of cost and demand are judged to be good if the calculation of cost-comparison coefficients is high. According to the Agency of Natural Resources and Energy, by regressing six explanatory variables with actual costs, the cost-comparison coefficients were calculated as half of the difference of the estimated value and the actual result[18].

Next, this paper estimated the cost function of power companies and then calculated the cost-comparison coefficients in a different way from that employed by the Agency of Natural Resources and Energy. Our coefficient must be more carefully refined than that used politically now in Japan's industrial policy because the latter is not based on any econometric procedure for estimating cost function. On the other hand, as competition progresses, the cost gap between various areas will become a social problem. Furthermore, it can be said that this paper revealed how much costs differed among electric power companies.

In order to analyze the determinants of the cost-comparison coefficients of electric power companies in detail, let us here regress the cost-comparison coefficients with (1) the demand density (the amount of electric power demanded, MWh, per contract), (2) the power-supply percentage (the ratio of maximum output of thermal power and nuclear electric power), and (3) the labor productivity (the amount of selling electric power per one employee). The average value of each explanatory variable of the electric power companies is displayed in Table 5, and the result of estimation is shown in Table 6. It can be observed that a cost-comparison coefficient is lower (that is, an average cost is higher), as the demand density is higher, as the percentage of power supply of thermal and nuclear electric power is higher, and as the labor productivity is lower.

<Table 5>

<Table 6>

We acknowledge that both a short-term, gradually regulatory reform and a long-term, radically regulatory reform are required in order to improve the Japanese electric power industry. For that, functional unbundling or even structural unbundling which some countries, including the U.K. and some American states, including California, adopted will be required in the foreseeable future. However, since structural reform takes time and is sometimes accompanied by uncertainty, the process of policy making should be prudently examined[19].

IX. Conclusion

There are two incentive effects in yardstick competition using cost-comparison coefficients discussed in this paper. First, if yardstick competition is introduced into a naturally monopolistic industry where competition seldom works, the improvement of management efficiency can be expected. Second, since the cost-comparison coefficients are calculated not on the basis of observed costs but on the basis of estimated costs, the cost-comparison assessment becomes generous for a company whose observed cost is lower than its estimated cost, see AC_{1B} in Figure 3, and stricter for a company whose observed cost is higher than its estimated cost, see AC_{0B} in Figure 3; in this respect, the effort of expense curtailment in the past is effectively reflected in the assessment, and the incentive to promote efficiency exists for the future as well.

Since the aims of our research are, first, to draw the cost-comparison coefficients by using the fixed effect model of panel data analysis, and, second, to propose a useful policy guideline toward regulatory reform, we have not daringly adopted complicated econometric models which much previous research has developed. Therefore, it is a future subject to reconsider the technique of our model in respect of refinement of models. As sometimes stated in footnotes, the following refinements will be needed: (1) the adoption of three outputs model in which transmission and distribution are considered separately, as well as power generation, (2) the adoption of generalized translog cost function like the Box-Cox transformation, (3) the estimation of the short-term cost function given that capital is quasi-fixed input and the verification of the existence of over-capitalization or under-capitalization, (4) the estimation of a cost function allowing for the regulatory bias and the various technical inefficiencies. We are fully aware of the questions stated above and consider them to be subjects for future research.

References

Baumol, W.J., J.C. Panzar and R.D. Willig, 1982, Contestable Markets and the Theory of Industrial Structure. Harcourt Brace and Jovanovich.

Baltagi, B.H., 1996, Econometric Analysis of Panel Data. John Wiley & Sons.

Christensen, L.R. and W.H. Greene, 1976, Economies of Scale in U.S. Electric Power Generation, Journal of Political Economy. 84.4, pp. 655-676.

Gilsdorf, K., 1994, Vertical Integration Efficiencies and Electric Utilities: Cost Complementary Perspectives, The Quarterly Review of Economics and Finance. 34.3, pp. 261-284.

Goto, M., and T. Sueyoshi, 1998, On the Economies of Scale of Japan's Electric Power Industry (written in Japanese), Koeki Jigyou Kenkyu (Journal of Public Utilities Economics). 50.1, pp. 1-7.

Hayashi, F. and T. Inoue, 1991, The Relation between Firm and Q with Multiple Capital Goods: Theory and Evidence from Panel Data on Japanese Firms, Econometrica. 59.3, pp. 731-753.

Hsiao, C., 1986, Analysis of Panel Data. Cambridge University Press.

Kaserman, D.L. and J.W. Mayo, 1991, The Measurement of Vertical Economies and the Efficient Structure of the Electric Utility Industry, Journal of Industrial Economics. 39.5, pp. 483-502.

Kerkvliet, J., 1991, Efficiency and Vertical Integration: the Case of Mine-Mouth Electric Generating Plants, Journal of Industrial Economics. 39.5, pp. 467-482.

Koike, N., 1999, An Empirical Analysis of the Yardstick Assessment of the Electric Power Industry (written in Japanese), Koeki Jigyou Kenkyu (Journal of Public Utilities Economics). 51.3, pp. 23-32 .

Krautmann, A.C. and J.L. Solow, 1988, Economies of Scale in Nuclear Power Generation. Southern Economic Journal, 55, pp. 70-85.

Nakanishi, Y. and N. Ito, 1998, On the Economies of Scale in the Electric Power Industry (written in Japanese). The Central Research Institute of Electric Power Industry Report, Y87017.

Nelson, R.A. and Wohar, M.E., 1983, Regulation, Scale Economies, and Productivity in Steam-Electric Generation. International Economic Review, 24.1, pp. 57-79.

Nemoto, J., Y. Nakanishi and S. Madono, 1993, Scale Economies and Over-Capitalization in Japanese Electric Utilities. International Economic Review, 34.2, pp. 431-441.

Shinjo, K. 1994, Natural Monopoly and Economies of Scale (written in Japanese). in: M. Uekusa (Ed.) Lectures on the Public Regulation and Industries vol. I, NTT Publication.

Torii, A., 1994, Regulation and Company Efficiency (written in Japanese). in: M. Uekusa (Ed.) Lectures on the Public Regulation and Industries vol. I, NTT Publication.

Toyama, Y., et al., 2000, Public Utility Industries in Japan. Michigan State University Papers.

Wales, T.J., 1977, On the Flexibility of Flexible Functional Forms. Journal of Econometrics, 5, pp. 183-193.

Watanabe, H. and M. Kitamura, 1994, The Economies of Vertical Integration in Japan's Electric Power Industry (written in Japanese). The Central Research Institute of Electric Power Industry Report, Y93016.

Watanabe, H. and M. Kitamura 1998, Analysis of the Long-term Cost Structure of Japan's Electric Power Industry (written in Japanese). The Central Research Institute of Electric Power Industry Report, Y97016.

Notes

---

[1] There are two kinds of panel data analysis: the fixed effect model and the random effect model (see Hsiao 1986, Baltagi 1996 for details). Which model should be adopted is dependent on the analytic purpose. On one hand, since the random effect model has the bias on its estimated value in the case where there is a correlation between constant term and explanatory variables, we have to verify the properness of using the random effect model. On the other hand, the fixed effect model has faults in that an economic interpretation of individually specific effects is sometimes difficult or that the degree of freedom in estimation is diminished by the dummy variables. At this moment, if the multi-collinearity among variables cannot be avoided and if the economic interpretation of the individually specific effect is relatively easy, such as in the electric power industry, the fixed effect model seems to be more desirable than the random effect model.

[2] The preceding studies of natural monopoly in the Japanese electric power industry can be briefly summarized as follows: it has been conventionally supposed that although Japan's electric power industry has exhibited the economies of scale-and-scope, the extent of this has gradually decreased (see Nakanishi and Ito 1987). On the other hand, several studies, taking the tendency of over-capitalization into consideration, have recently revealed that the economies of scale would almost disappear in the long-term (see Nemoto, et al. 1993, Watanabe and Kitamura 1997, Goto and Sueyoshi 1998 for example). For a general discussion about the Japanese network utilities, Toyama 2000 will be informative.

[3] In 1972, the Okinawa Electric Power Co., Inc. (a public corporation) was launched following the return of Okinawa to Japan. The company was later privatized in 1988, bringing the total of electric power companies in Japan to ten.

[4] The industrial structure of electric power should originally be divided into three outputs: generation, transmission, and distribution. However, there is a strong correlation between transmission and distribution. As a result, the econometric problem of multi-collinearity will occur and adversely affected the estimates. For this reason, we here adopt the two-outputs model considering transmission and distribution as one output. In addition to this, there seems no agreement concerning the definition of the output of transmission-and-distribution, and various definitions have been given so far. Although Gilsdorf (1994) defines the output of transmission-and-distribution as the product of them, the difference of this output among companies becomes too large because of the multiplying procedure. Therefore, we will define the output of transmission-and-distribution as the geometric mean of transmission and distribution.

[5] As deflator, we use the capital-goods price index reported in the Price Index Statistics of the Bank of Japan for capital, gross investment, and depreciation expenses, and the GDP deflator for others.

[6] It is often said that the tendency of over-capitalization exists in the electric power industry and capital is not adjusted to the optimum level. Though not indicated here, we estimated the short-term cost function in the case where capital is considered as quasi-fixed input, besides the long-term cost function, and confirmed that the tendency of over-capitalization existed in the Japanese electric power industry.

[7] The estimated value of coefficients dropped from the constraint of linear homogeneity are the following: b_K=0.456941, b_{LL} =0.11048, b_{FF} =0204157, b_{KK} =0.2472703, d_{K1}=-0.016975, d_{K2}=0.000956.

[8] We have to check ex post whether the monotonicity and concavity of input prices and the monotonicity of outputs are satisfied according to all samples. The possibility that the conditions mentioned above may not be satisfied in the case of extremely small values may bring into question the properness of the translog cost function. It is true that there are some cases where the monotonicity of output is not satisfied in our estimation. However, some research demonstrating that the adoption of translog cost function does not necessarily cause a serious problem is also known (see Wales 1977 for details).

[9] It may be suitable to use an expression called the economies of vertical integration rather than economies of scope since power generation and transmission-and-distribution can be considered as a vertically continuous stage in the production of electric power. See Kaserman and Mayo (1991) concerning the more discussions of vertical economies.

[10] See Baumol, Panzar and Willig (1982) concerning the more discussions of economies of scale-and-scope.

[11] Originally, the economies of scope should be judged by whether or not the sum of each stand-alone cost exceeds the overall cost. However, since we cannot assume output=0 due to the intrinsic nature of translog cost function, we here substitute the weak complementarities of cost for the test of economies of scope. In fact, the weak complementarities are only a sufficient condition for the economies of scope. A device that adopts the generalized translog cost function, such as using the Box-Cox transformation, is also an idea so that output = 0 can be set.

[12] It should be noted that benefiting from the economies of scale does not necessarily concord with producing much output because the economies of scale are influenced by the difference in input prices of each company. And it is because the partial derivatives of outputs on the total cost are negative that the figures of Hokuriku and Shikoku sometimes exceed 1 in several years. In this respect, our estimation model may not be proper. However, the economies of scale still exist in such a case.

[13] We understand that such an artificial method of aggregation of units may be problematic. Instead of aggregation, we can adopt a method of calculating the cost-comparison coefficient respectively depending on each output. In the case where our result is discussed for an actual policy, the respective cost-comparison coefficient for each output will become a finer measure. Otherwise, we can adopt monetary

units such as sales so that they can be easily aggregated altogether.

[14] The average cost of company B for output Y_B is $AC_B(Y_B)$. When the individually specific effect of firm B is not taken into consideration, namely K_B=0, the average cost of company B for output Y_B is $AC_A(Y_B)$.

[15] When the individually specific effect of firm B is not taken into consideration, namely K_B=0, the average cost of company B for output Y_B is $AC_A(Y_B)$ and the average cost of company B for output Y_A is $AC_A(Y_A)$.

[16] The average cost of company B for output Y_B is $AC_B(Y_B)$. When the individually specific effect of firm B is not taken into consideration, namely K_B=0, the average cost of company B for output Y_A is $AC_A(Y_A)$.

[17] This result is very different from the general belief that the cost per kWh of Hokkaido is much higher than those of others. One reason for this is that the output of transmission-and-distribution becomes very large especially in Hokkaido whose area is very large when we define output to include transmission-and-distribution as well as generation.

[18] Six explanatory variables are the following: (1) the power consumed per contract, (2) the ratio of metropolitan areas, (3) the ratio of consumer of electricity whose voltage is less than 6000 V, (4) the number of contracts divided by the service area, (5) the power consumed per power line, and (6) the maximum capacity of power generation of each company. However, it is sometimes pointed out that there is a multi-collinearity among six variables (see Koike 1999).

[19] Here we do not enter into the further discussion of unbundling of the Japanese electric power industry because we need to estimate the cost functions of both vertically integrated and non-integrated firms for this (see Kerkvliet 1991 for more details). Unfortunately, the history of the Japanese deregulation is not so long that the data must be accumulated enough to be tested.

Table 1: The estimation result of translog cost function

Variable	a_1(Hokkaido)	a_2(Tohoku)	a_3(Tokyo)	a_4(Chubu)	a_5(Hokuriku)	a_6(Kansai)	a_7(Chugoku)	a_8(Shikoku)	a_9(Kyushu)	b_L	b_F	b_{LF}
Coefficient	-0.5018	-0.0898	0.5387	0.1529	-0.6572	0.2923	-0.1567	-0.5269	-0.3758	0.2315	0.3116	-0.0360
Standard Error	0.0588	0.0141	0.0859	0.0270	0.1216	0.0490	0.0286	0.0953	0.0219	0.0041	0.0121	0.0042
t-Ratio	-8.5316	-6.3806	6.2687	5.6544	-5.4066	5.9614	-5.4699	-5.5318	-17.1679	56.9629	25.7705	-8.5504
Variable	b_{LK}	b_{FK}	c_1	c_2	c_{11}	c_{22}	c_{12}	d_{L1}	d_{L2}	d_{F1}	d_{F2}	e_{L1}
Coefficient	-0.0745	-0.1682	0.3288	0.1859	0.2755	0.3861	-0.2611	-0.0346	0.0090	0.0516	-0.0186	-0.0001
Standard Error	0.0061	0.0135	0.0435	0.0873	0.0844	0.1379	0.0983	0.0042	0.0047	0.0111	0.0125	0.0034
t-Ratio	-12.1718	-12.4826	7.5587	2.1298	3.2650	2.7990	-2.6556	-8.3176	1.9085	4.6369	-1.4853	-0.0157
Variable	e_{L2}	e_{L3}	e_{L4}	e_{L5}	e_{L6}	e_{L7}	e_{L8}	e_{L9}	e_{L10}	e_{L11}	e_{L12}	e_{L13}
Coefficient	-0.0238	-0.0380	-0.0387	-0.0431	-0.0445	-0.0475	-0.0533	-0.0565	-0.0587	-0.0632	-0.0715	-0.0789
Standard Error	0.0040	0.0052	0.0054	0.0054	0.0048	0.0047	0.0045	0.0046	0.0048	0.0051	0.0051	0.0050
t-Ratio	-5.9235	-7.2727	-7.1761	-7.9796	-9.3101	-10.1296	-11.8039	-12.2019	-12.2714	-12.4740	-14.1351	-15.8730
Variable	e_{L14}	e_{L15}	e_{L16}	e_{L17}	e_{L18}	e_{L19}	e_{L20}	e_{L21}	e_{F1}	e_{F2}	e_{F3}	e_{F4}
Coefficient	-0.0849	-0.0860	-0.0912	-0.0924	-0.0950	-0.0968	0.1043	-0.1059	-0.0295	-0.0312	-0.0537	-0.0733
Standard Error	0.0052	0.0056	0.0061	0.0065	0.0067	0.0067	0.0069	0.0080	0.0148	0.0166	0.0181	0.0175
t-Ratio	-16.1914	-15.3693	-14.9661	-14.1393	-14.1197	-14.4849	15.0616	-13.2974	-1.9894	-1.8799	-2.9714	-4.1798
Variable	e_{F5}	e_{F6}	e_{F7}	e_{F8}	e_{F9}	e_{F10}	e_{F11}	e_{F12}	e_{F13}	e_{F14}	e_{F15}	e_{F16}
Coefficient	-0.0868	-0.1007	-0.1041	-0.1172	-0.1220	-0.1253	-0.1169	-0.1057	-0.0932	-0.0942	-0.1022	-0.1172
Standard Error	0.0178	0.0167	0.0163	0.0159	0.0156	0.0154	0.0156	0.0156	0.0154	0.0157	0.0157	0.0163
t-Ratio	-4.8729	-6.0252	-6.3848	-7.3748	-7.8100	-8.1135	-7.4724	-6.7938	-6.0631	-6.0123	-6.5070	-7.1942
Variable	e_{F17}	e_{F18}	e_{F19}	e_{F20}	e_{F21}	f_{t1}	f_{t2}	f_{cu}				
Coefficient	-0.1192	-0.1258	-0.1231	-0.1181	-0.1082	0.0358	-0.0002	-0.1465				
Standard Error	0.0163	0.0162	0.0157	0.0158	0.0162	0.0037	0.0001	0.0323				
t-Ratio	-7.2978	-7.7855	-7.8633	-7.4586	-6.6742	9.6089	-2.0666	-4.5312				

Cost-function-adjusted-R^2=0.995626/Labor-share-adjusted-R^2=0.860541/Fuel-share-adjusted-R^2=0.910049

Table2: The economies of scale and scope (standard value)

Variable	Overall economies of scale	Economies of scale of Y_1	Economies of scale of Y_2	Economies of scope
Coefficient	0.4853	0.6712	0.8141	-0.2000
Standard Error	0.0853	0.0435	0.0873	0.1022
t-Ratio	5.6895	15.4304	9.3290	-1.9573

Table3: The economies of scale and scope

		1978-83	1984-88	1989-93	1994-98	Average
Hokkaido	Overall economies of scale	0.5608	0.5531	0.5566	0.5556	0.5565
	Economies of scale of Y_1	0.7102	0.7160	0.7034	0.7006	0.7075
	Economies of scale of Y_2	0.8506	0.8371	0.8532	0.8550	0.8490
	Economies of scope	-0.4006	-0.3603	-0.2999	-0.2454	-0.3265
Tohoku	Overall economies of scale	0.6325	0.6361	0.6301	0.6378	0.6341
	Economies of scale of Y_1	0.6609	0.6849	0.6789	0.6495	0.6686
	Economies of scale of Y_2	0.7915	0.7701	0.7786	0.8038	0.7860
	Economies of scope	-0.2083	-0.1791	-0.1518	-0.1137	-0.1632
Tokyo	Overall economies of scale	0.3251	0.3266	0.3244	0.3208	0.3242
	Economies of scale of Y_1	0.5357	0.5278	0.5094	0.5153	0.5220
	Economies of scale of Y_2	0.7894	0.7988	0.8150	0.8055	0.8022
	Economies of scope	-0.0680	-0.0535	-0.0432	-0.0357	-0.0501
Chubu	Overall economies of scale	0.4318	0.4351	0.4375	0.4354	0.4349
	Economies of scale of Y_1	0.5095	0.5148	0.5100	0.5184	0.5132
	Economies of scale of Y_2	0.9223	0.9203	0.9275	0.9170	0.9218
	Economies of scope	-0.1910	-0.1521	-0.1236	-0.1017	-0.1421
Hokuriku	Overall economies of scale	0.6343	0.6502	0.6528	0.6535	0.6477
	Economies of scale of Y_1	0.5754	0.6503	0.6163	0.5804	0.6056
	Economies of scale of Y_2	1.0589	0.9999	1.0365	1.0732	1.0421
	Economies of scope	-1.1017	-1.0381	-0.8140	-0.6141	-0.8920
Kansai	Overall economies of scale	0.3910	0.3908	0.3933	0.3962	0.3928
	Economies of scale of Y_1	0.5429	0.5457	0.5385	0.5423	0.5423
	Economies of scale of Y_2	0.8481	0.8451	0.8547	0.8540	0.8505
	Economies of scope	-0.1103	-0.0946	-0.0793	-0.0721	-0.0891
Chugoku	Overall economies of scale	0.5045	0.5158	0.5200	0.5159	0.5141
	Economies of scale of Y_1	0.6215	0.6946	0.6531	0.6407	0.6525
	Economies of scale of Y_2	0.8830	0.8212	0.8669	0.8753	0.8616
	Economies of scope	-0.3350	-0.3130	-0.2455	-0.1992	-0.2732
Shikoku	Overall economies of scale	0.6069	0.6096	0.6160	0.6105	0.6108
	Economies of scale of Y_1	0.5645	0.5946	0.5928	0.5782	0.5825
	Economies of scale of Y_2	1.0424	1.0150	1.0232	1.0323	1.0282
	Economies of scope	-0.7776	-0.6379	-0.5660	-0.4385	-0.6050
Kyusyu	Overall economies of scale	0.4704	0.4791	0.5631	0.5887	0.5253
	Economies of scale of Y_1	0.6251	0.6551	0.6365	0.6122	0.6322
	Economies of scale of Y_2	0.8453	0.8141	0.8403	0.8574	0.8393
	Economies of scope	-0.2527	-0.2127	-0.1714	-0.1342	-0.1927
Average	Overall economies of scale	0.5064	0.5107	0.5215	0.5238	0.5156
	Economies of scale of Y_1	0.5940	0.6204	0.6043	0.5931	0.6029
	Economies of scale of Y_2	0.8924	0.8691	0.8884	0.8970	0.8867
	Economies of scope	-0.3828	-0.3379	-0.2772	-0.2172	-0.3038

Table 4: The cost-comparison coefficients						
		1978-83	1984-88	1989-93	1994-98	Average
Hokkaido	α(individual effect)	1.6517	1.6517	1.6517	1.6517	1.6517
	β(scale-and-scope economies)	0.8593	0.8091	0.7559	0.8486	0.8182
	γ(comprehensive)	1.4194	1.3363	1.2486	1.4016	1.3515
Tohoku	α(individual effect)	1.0940	1.0940	1.0940	1.0940	1.0940
	β(scale-and-scope economies)	1.0309	1.0555	0.9953	1.0459	1.0319
	γ(comprehensive)	1.1279	1.1547	1.0889	1.1442	1.1289
Tokyo	α(individual effect)	0.5835	0.5835	0.5835	0.5835	0.5835
	β(scale-and-scope economies)	1.6606	1.7805	1.7674	1.7081	1.7292
	γ(comprehensive)	0.9690	1.0389	1.0313	0.9967	1.0090
Chubu	α(individual effect)	0.8582	0.8582	0.8582	0.8582	0.8582
	β(scale-and-scope economies)	1.1628	1.2956	1.2744	1.2251	1.2395
	γ(comprehensive)	0.9980	1.1119	1.0937	1.0515	1.0637
Hokuriku	α(individual effect)	1.9293	1.9293	1.9293	1.9293	1.9293
	β(scale-and-scope economies)	0.5369	0.5164	0.5304	0.5194	0.5258
	γ(comprehensive)	1.0358	0.9964	1.0233	1.0021	1.0144
Kansai	α(individual effect)	0.7466	0.7466	0.7466	0.7466	0.7466
	β(scale-and-scope economies)	1.4596	1.4727	1.4502	1.4567	1.4598
	γ(comprehensive)	1.0897	1.0995	1.0827	1.0875	1.0898
Chugoku	α(individual effect)	1.1697	1.1697	1.1697	1.1697	1.1697
	β(scale-and-scope economies)	0.9097	0.8814	0.8862	0.8693	0.8866
	γ(comprehensive)	1.0640	1.0309	1.0365	1.0167	1.0371
Shikoku	α(individual effect)	1.6937	1.6937	1.6937	1.6937	1.6937
	β(scale-and-scope economies)	0.6493	0.6716	0.6451	0.6534	0.6548
	γ(comprehensive)	1.0997	1.1375	1.0926	1.1066	1.1091
Kyushu	α(individual effect)	1.0000	1.0000	1.0000	1.0000	1.0000
	β(scale-and-scope economies)	1.0000	1.0000	1.0000	1.0000	1.0000
	γ(comprehensive)	1.0000	1.0000	1.0000	1.0000	1.0000

Table 5: The mean values of explanatory variables (1978-1998)

	The demand density	The thermal power ratio	The nuclear power ratio	The labor productivity
Hokkaido	6.3834	0.6719	0.0923	3105.8
Tohoku	7.9200	0.7212	0.0469	3693.3
Tokyo	8.9096	0.6328	0.2316	4780.7
Chubu	10.6485	0.7220	0.1031	4446.8
Hokuriku	11.9573	0.5558	0.0279	3531.7
Kansai	10.0612	0.5348	0.2525	4328.8
Cyugoku	9.1076	0.6691	0.0953	3570.3
Shikoku	7.9181	0.5979	0.2277	2857.0
Kyusyu	7.6126	0.6471	0.1946	3592.8

Table 6: The estimation result of the cost-comparison coefficients

Variable	The constant term	The demand density	The thermal power ratio	The nuclear power ratio	The labor productivity
Coefficient	1.6705	-0.0415	-0.4047	-0.6145	0.000034
Standard Error	0.1155	0.0064	0.1316	0.1194	0.000012
t-Ratio	14.4594	-6.5354	-3.0757	-5.1485	2.7874
Adjusted-R^2=0.277721					

Figure 1: Japan's nine incumbent power companies

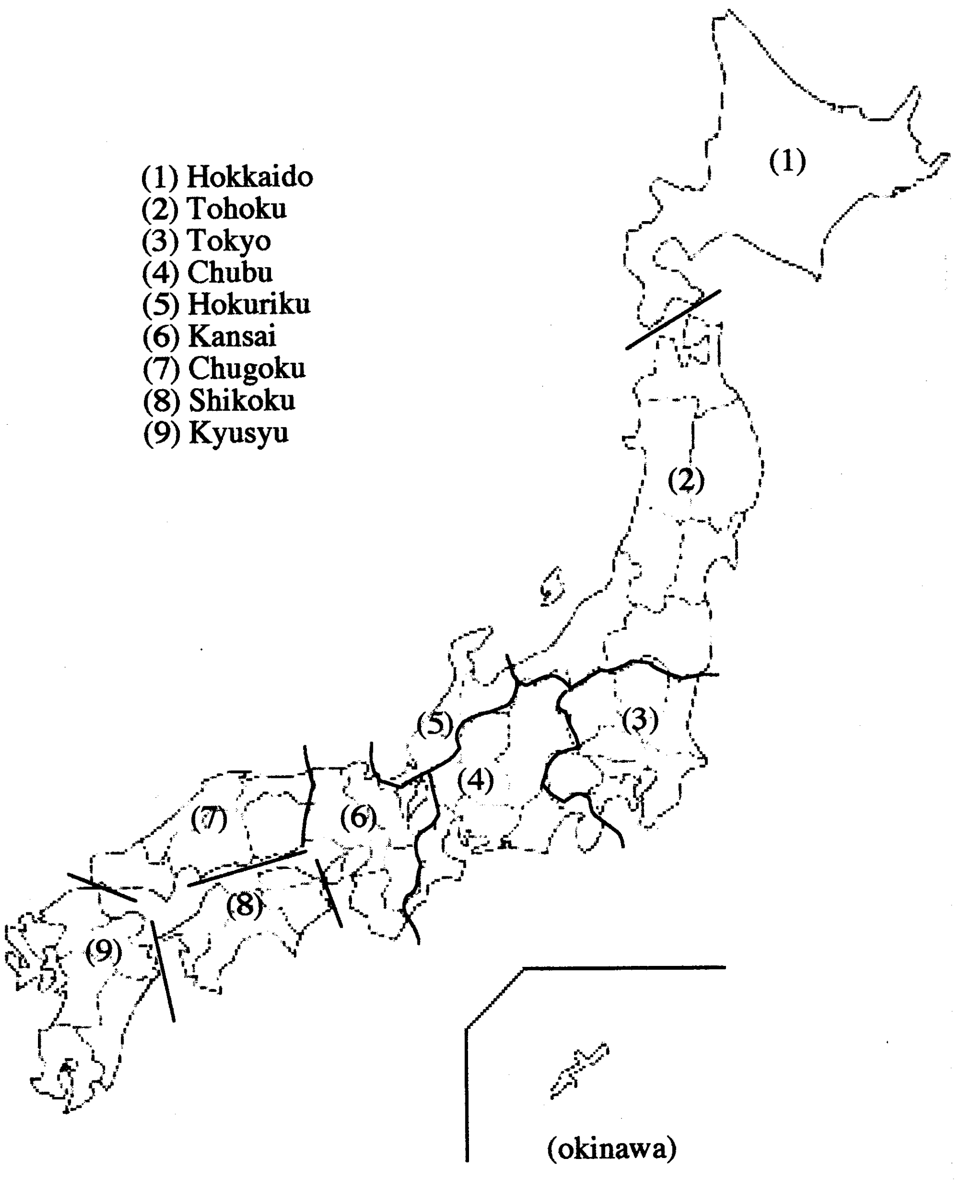

Figure 2: The economies of scale and scope (1978-98)

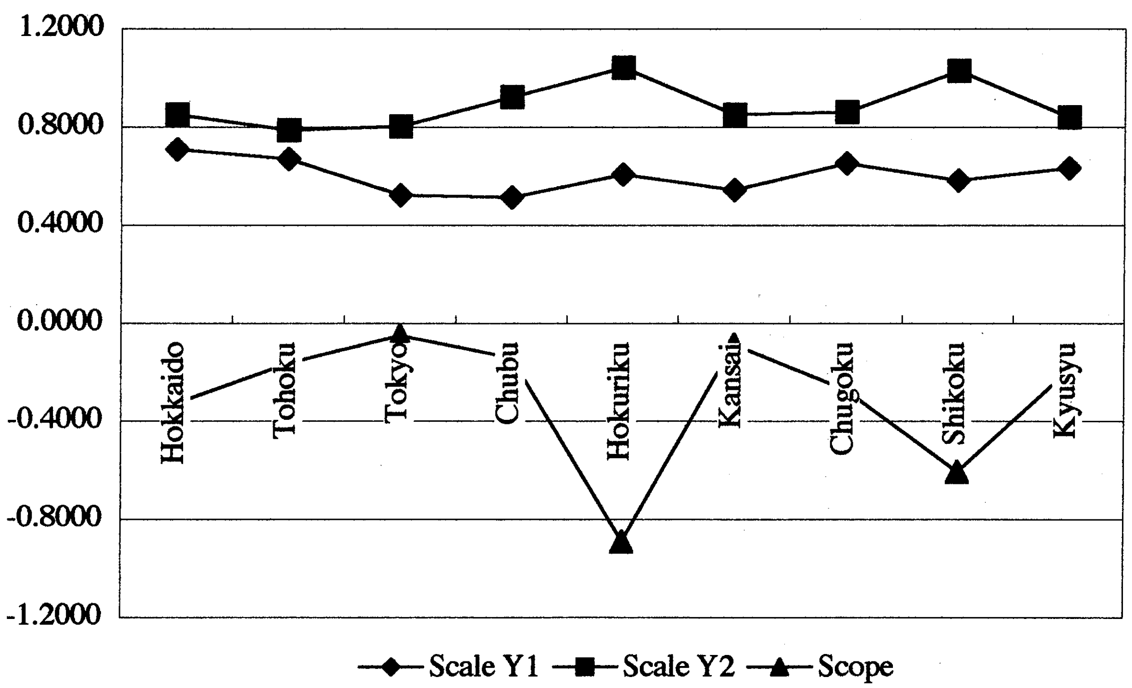

Figure 3: The incentive effects of cost-comparison coefficients

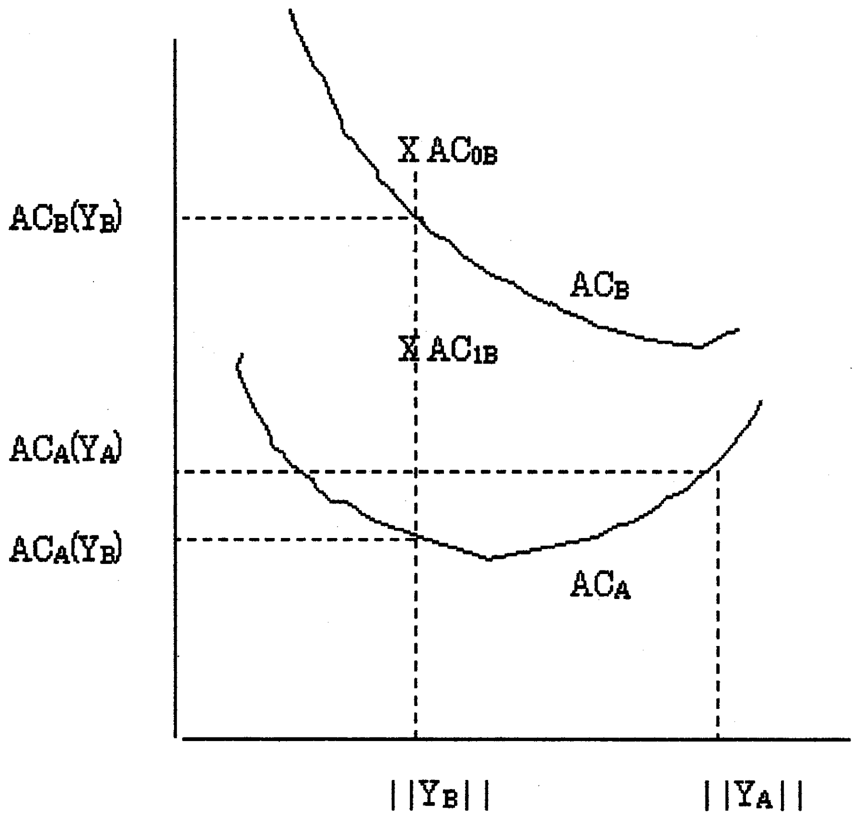

Figure 4: The cost-comparison coefficients (1978-98)